3.1.7. TROPOSPHERIC OZONE

Surface ozone measurements continued at nine monitoring sites that include the four CMDL observatories, Niwot Ridge, and four sites in the North Atlantic. Many of the significant characteristics of the ozone distribution at these sites are discussed in *Oltmans and Levy* [1994].

At SPO the 20-year record of surface observations has shown significant ozone concentration decreases [*Schnell et al.*, 1991; *Oltmans and Levy*, 1994]. The largest and most significant declines occurred in the summer (DEC-JAN-FEB) and autumn (MAR-APR-MAY). In recent years, however, the decline has slowed in the summer but has become more pronounced during the rest of the year, particularly the autumn. The summer declines reported earlier were linked to the expected increase in ultraviolet radiation associated with the dramatic decline in stratospheric ozone over Antarctica and the consequent enhancement in tropospheric ozone loss [*Schnell et al.*, 1991]. Coupled with greater photochemical destruction of ozone was an increased transport from the coast of Antarctica to the interior of the continent bringing air with less ozone to the Pole. There are indications that transport patterns may have returned to those seen prior to 1980 [*Peterson and Rosson*, 1993]. Surface ozone values have not, however, recovered.

A plot of the smoothed, monthly mixing ratios (Figure 3.8) shows surface ozone beginning to decline in 1986 and then more dramatically after 1989 remaining relatively low in recent years. During the springs of 1991-1993, the lower stratosphere (below 14 km) has had particularly low ozone amounts [*Hofmann et al.*, 1994*a*]. This represents a significant downward extension in altitude of the ozone depletion region as a result of the presence of greatly enhanced sulfate aerosol from Mt. Hudson (1991) and Mt. Pinatubo (1992 and 1993) and the resulting heterogeneous destruction of ozone. The lowest seasonal minimum values in surface ozone were recorded in the late summer following each of these years.

Although differing a bit in detail, the ozonesonde record that began in 1986 shows a remarkably similar result for measurements obtained near the surface (600 mb). The ozonesonde data (Figure 3.9) also show that the recent (1991-1993) low values at the surface appear throughout the troposphere and into the lower stratosphere. This suggests that the additional decline seen in recent years at SPO is related to the large spring and early summer deficit in the lower stratospheric reservoir that feeds ozone into the upper stratosphere by cross-tropopause flux processes and thus reduces the contribution from the stratosphere to the tropospheric burden. Since the ozonesonde record does not encompass the period of more gradual decline seen at the surface prior to 1987, it is not possible to determine whether a portion of that earlier decrease was a result of a diminishment of the lower stratospheric reservoir. There is some evidence that in 1986-1991 the ozone in the lowest part of the stratosphere was lower than during 1967-1971 when there is a set of ozone vertical profile measurements at SPO (*Oltmans et al.*, 1994).

Table 3.11 gives the monthly mean ozone mixing ratios for the sites where data is available through 1993.

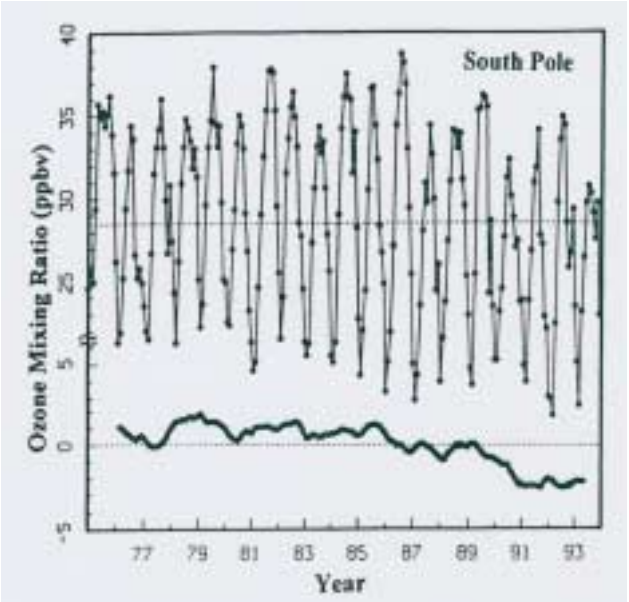

Fig. 3.8. Monthly means and smoothed monthly departures from the long-term monthly mean surface ozone mixing ratios at South Pole. The smoothing is a 24-month running mean.

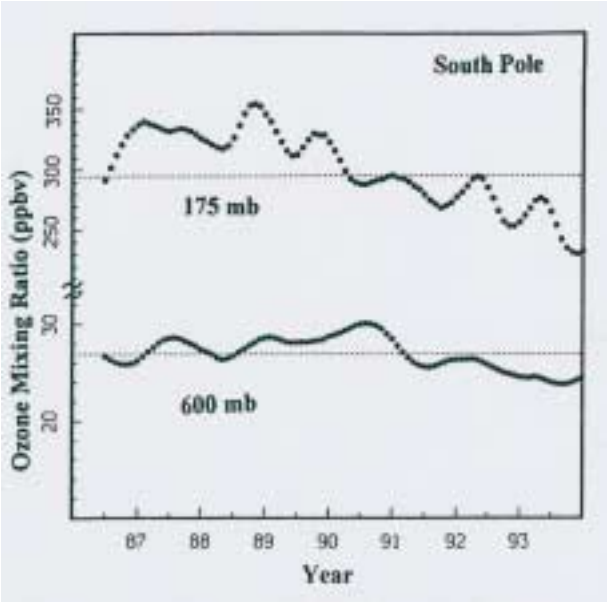

Fig. 3.9. Smoothed monthly departures from the long-term monthly mean ozone mixing ratios for the lower troposphere (600 mb) and lower stratosphere (175 mb). The data are from weekly ozonesonde observations.

TABLE 3.11. Monthly Mean Surface Ozone Mixing Ratios (ppbv) During 1992 and 1993

Station	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Westman Is., Ireland	1993	39.7	41.4	45.1	45.4	44.3	34.7	27.3	28.8	33.0	37.4	38.0	34.2
Mace Head, Ireland	1993	37.2	33.5	38.8	40.6	39.3	30.4	28.3	29.0	30.3	24.2	28.9	36.5
NWR	1993	37.7	40.6	42.7	46.7	43.3	44.0	43.6	39.0	37.2	36.6	43.6	41.9
Bermuda	1993	36.4	38.6	38.7	42.8	36.6	32.2	25.2	22.5		32.4	32.6	34.6
Barbados	1992	23.3	23.3	21.5	19.5	16.4	16.3	17.1		18.4		21.6	24.4
	1993	26.3	22.3	24.7	19.7	18.6	21.6	20.4		14.5	17.8	23.5	26.3